Methods Of Crater And Spall Repair

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Purpose

- Describe the different methods of crater and spall repair
- Give the student the basic understanding of crater and spall repair to enable them to estimate and execute RRR

Enabling Learning Objectives

- Identify the types of runway damage that could result from an attack on an airfield
- Identify and describe the ten crater repair steps
- Describe the four methods used to effect crater repairs and describe the characteristics of each
- State the four methods of FOD cover used by the Marine Corps to complete crater repairs
- Identify the different spall repair materials, their characteristics, and how they used to effect a spall repair

Expected Damage Weapon Types

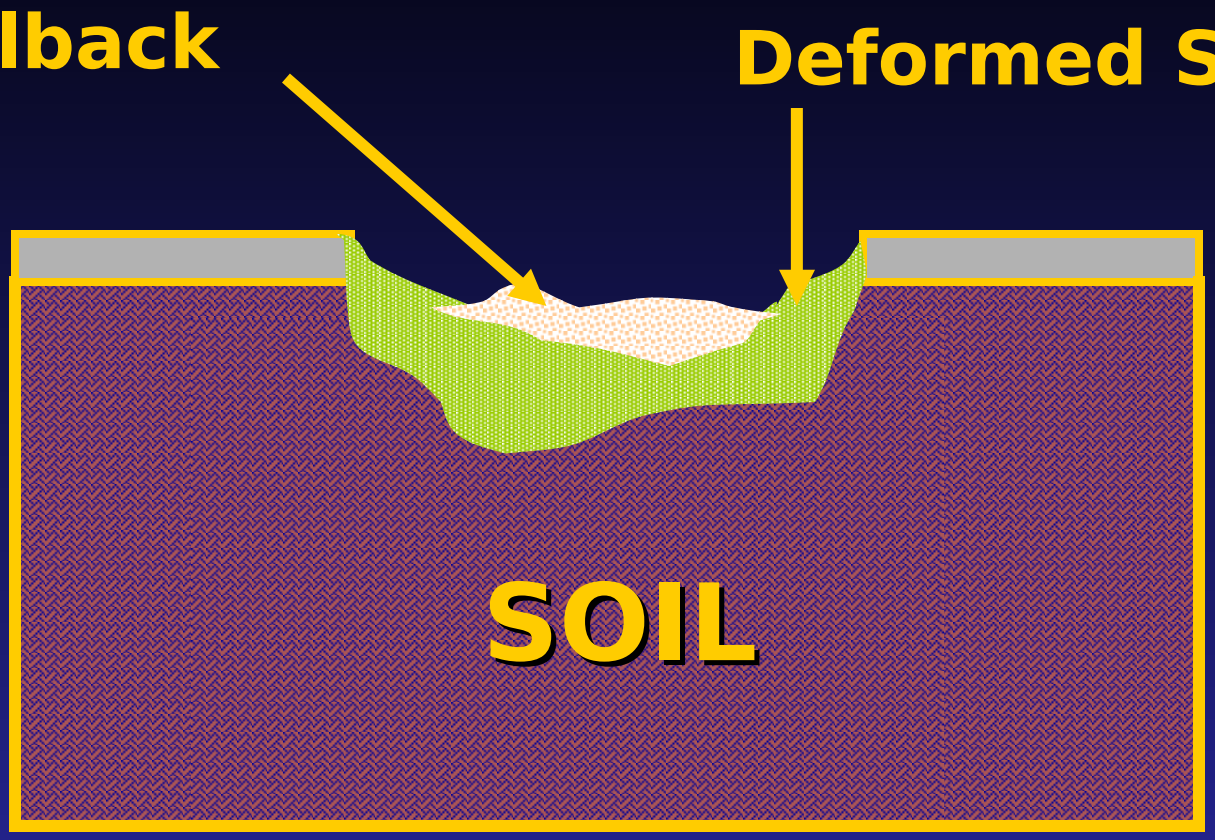
- Air delivered, general purpose bombs and small caliber munitions
- Bomblets from air delivered cluster bombs
- Naval gunfire and Artillery
- Land-based, surface-based, and air-launched rockets and missiles
- Chemical and biological munitions
- Demolitions

Expected Damage Projectile Fuzing

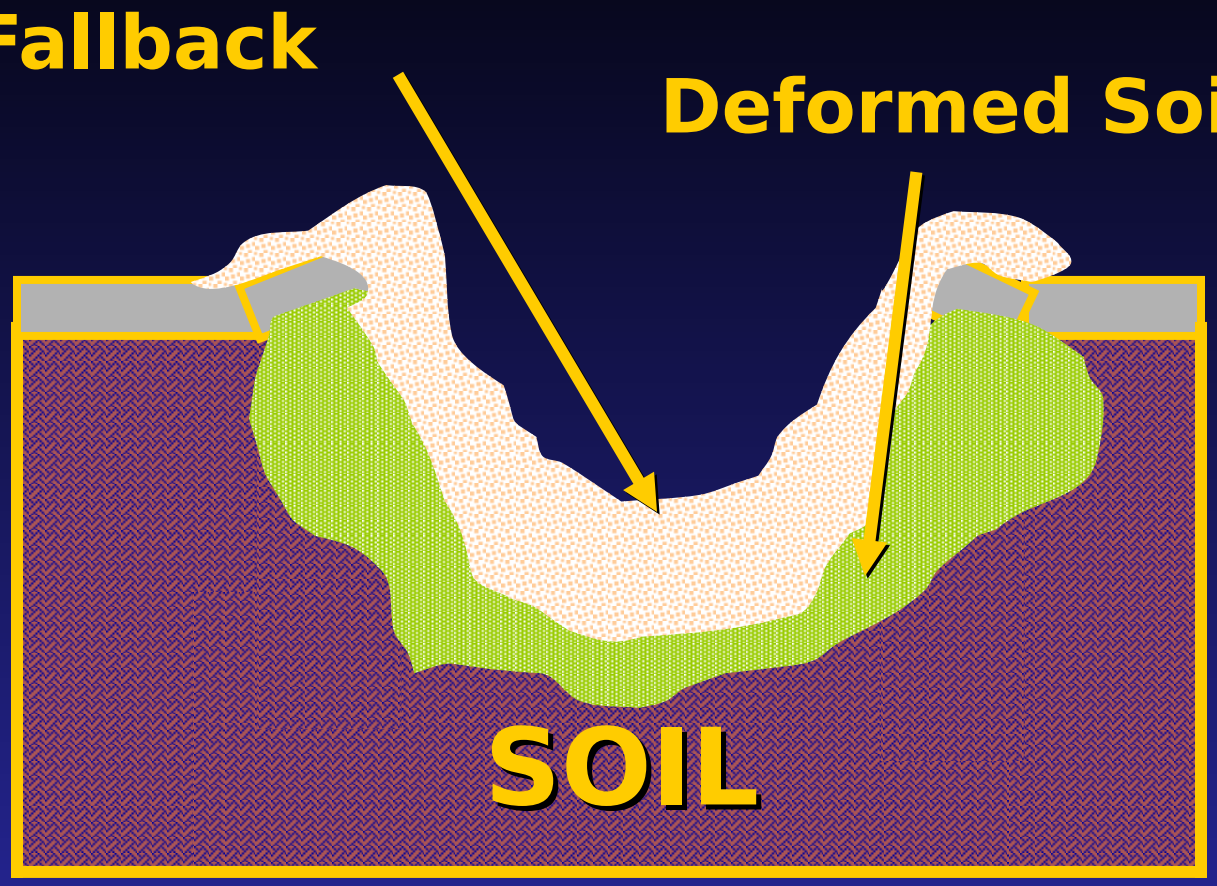
- Instantaneous contact fuses
- Short time delay fuses
- Long time delay fuses
- Proximity fuses
- Air burst
- Anti-withdrawal
- Anti-disturbance
- Magnetic
- Acoustic

Expected Damage Types Of Bursts

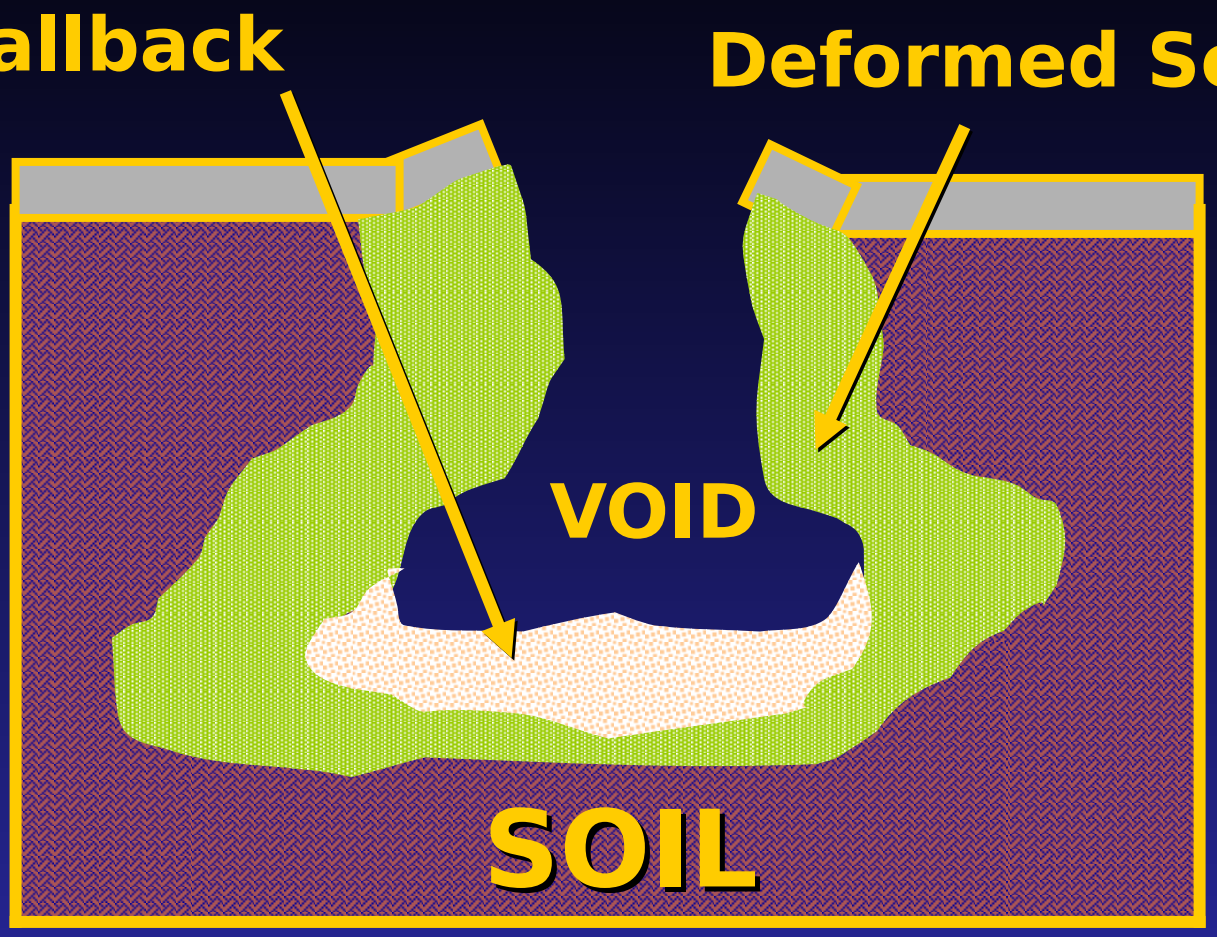
- Surface Burst
  - Causes surface penetration
- Optimum Burst
  - Causes maximum volume of repair damage
- Deep Burst
  - Causes camouflets



Surface Burst (Shallow Penetration)



Optimum Depth of Burst (Maximum Repair Volume)



Deep Burst (Camoflet)

Expected Damage Damage Profile

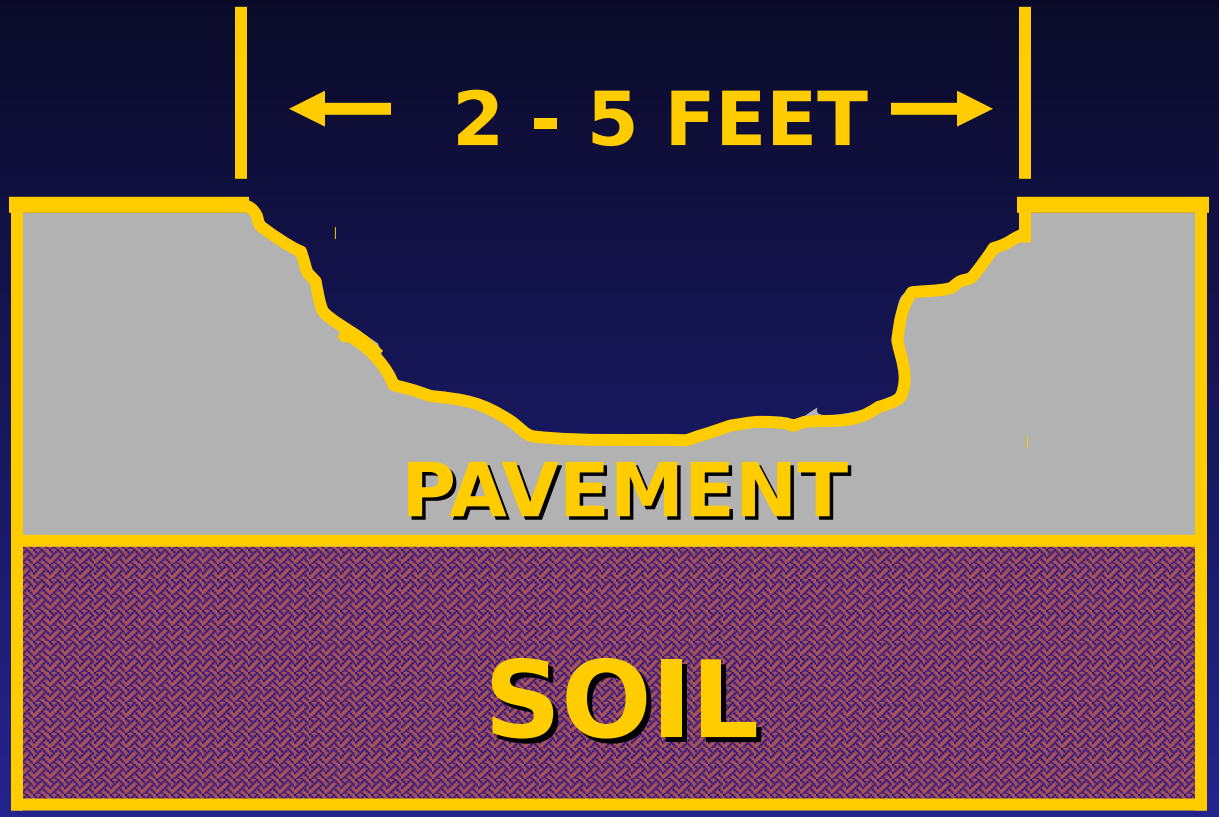
- Actual damage diameter is greater than apparent damage diameter
- Debris and fallback from the detonation generally obscures the up heaved pavement around the crater and the actual depth of the crater
- Camouflets are characterized by relatively small apparent damage diameters, but have deep subsurface damage

Expected Damage
Damage Categories

- Spalls and Scabs
- Craters
  - Small Craters
  - Large Craters
- Camouflets

Damage Categories

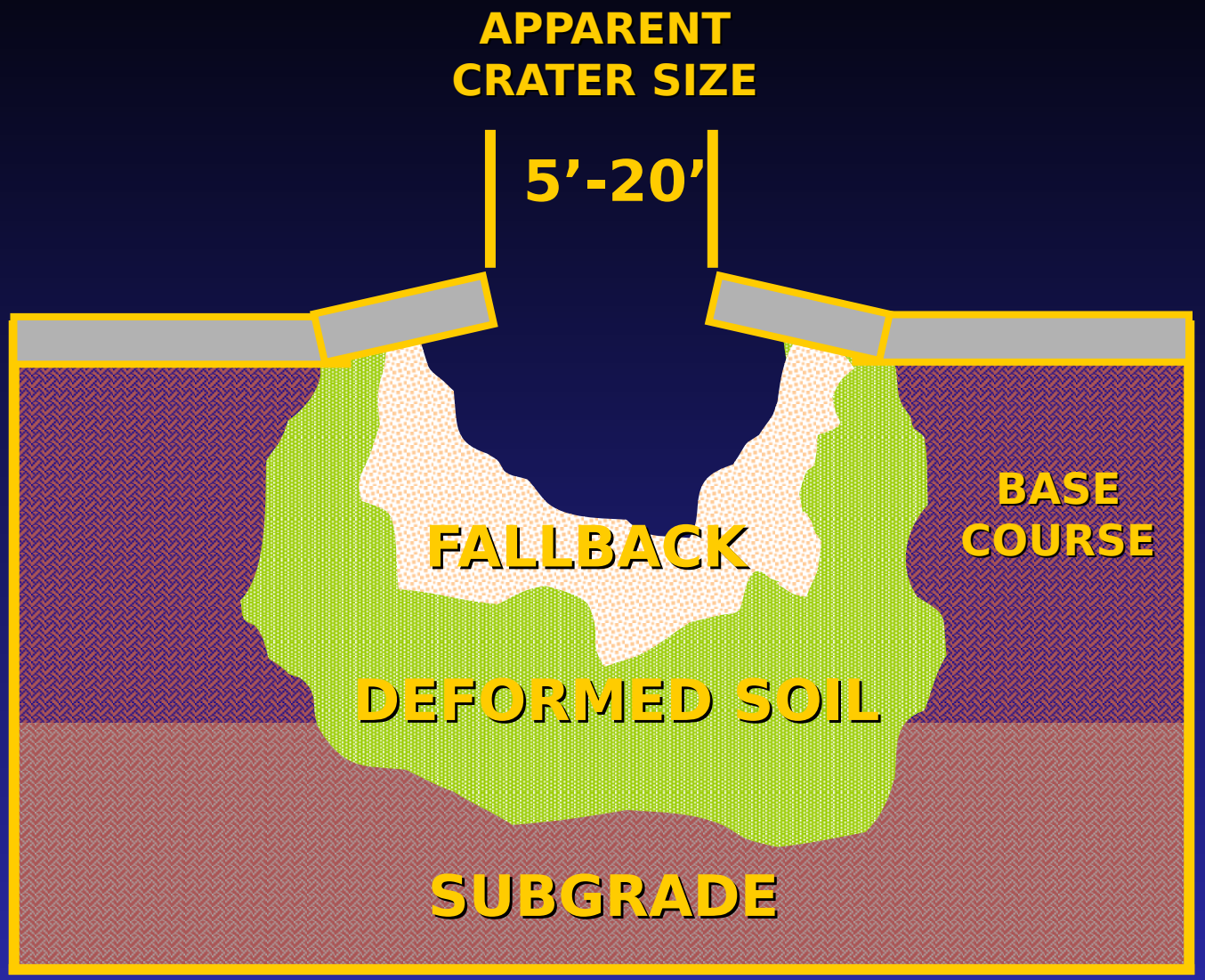
- Spalls and Scabs
  - Considered craters that are less than 5 feet in diameter
  - Do not penetrate the runway base course and sub-grade
  - Generally caused by small bombs, small caliber artillery, small rocket fire, or small caliber contact fused munitions



SPALL / SCAB

Damage Categories

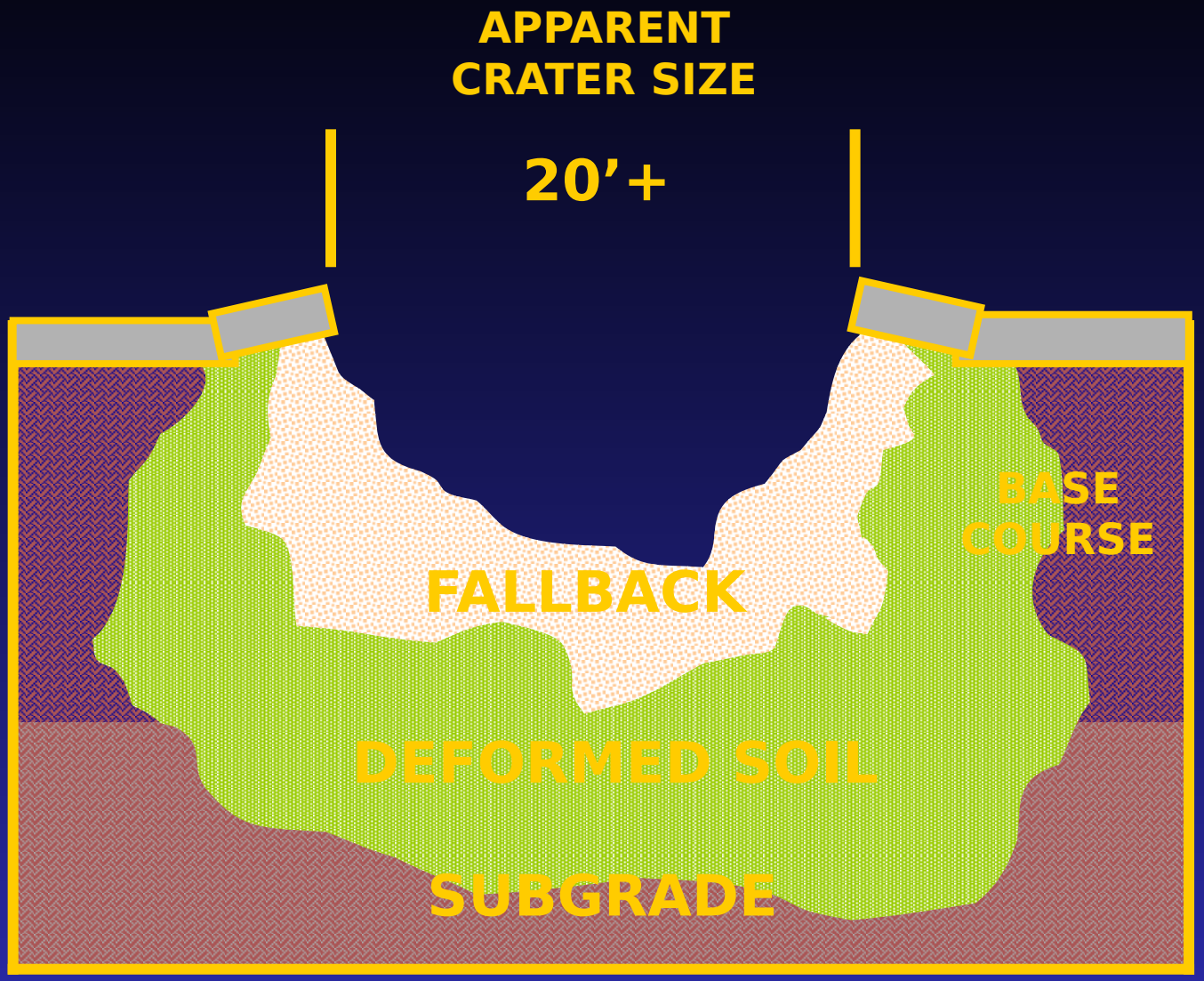
- Small Craters
  - Craters that are less than 20 feet in apparent diameter
  - Penetrate the base course and sub-grade of the runway
  - Usually caused by 500 pounds or less bombs, high-angle medium caliber naval gunfire, or large rocket fire
  - May not have pavement upheaval



Small Crater

Damage Categories

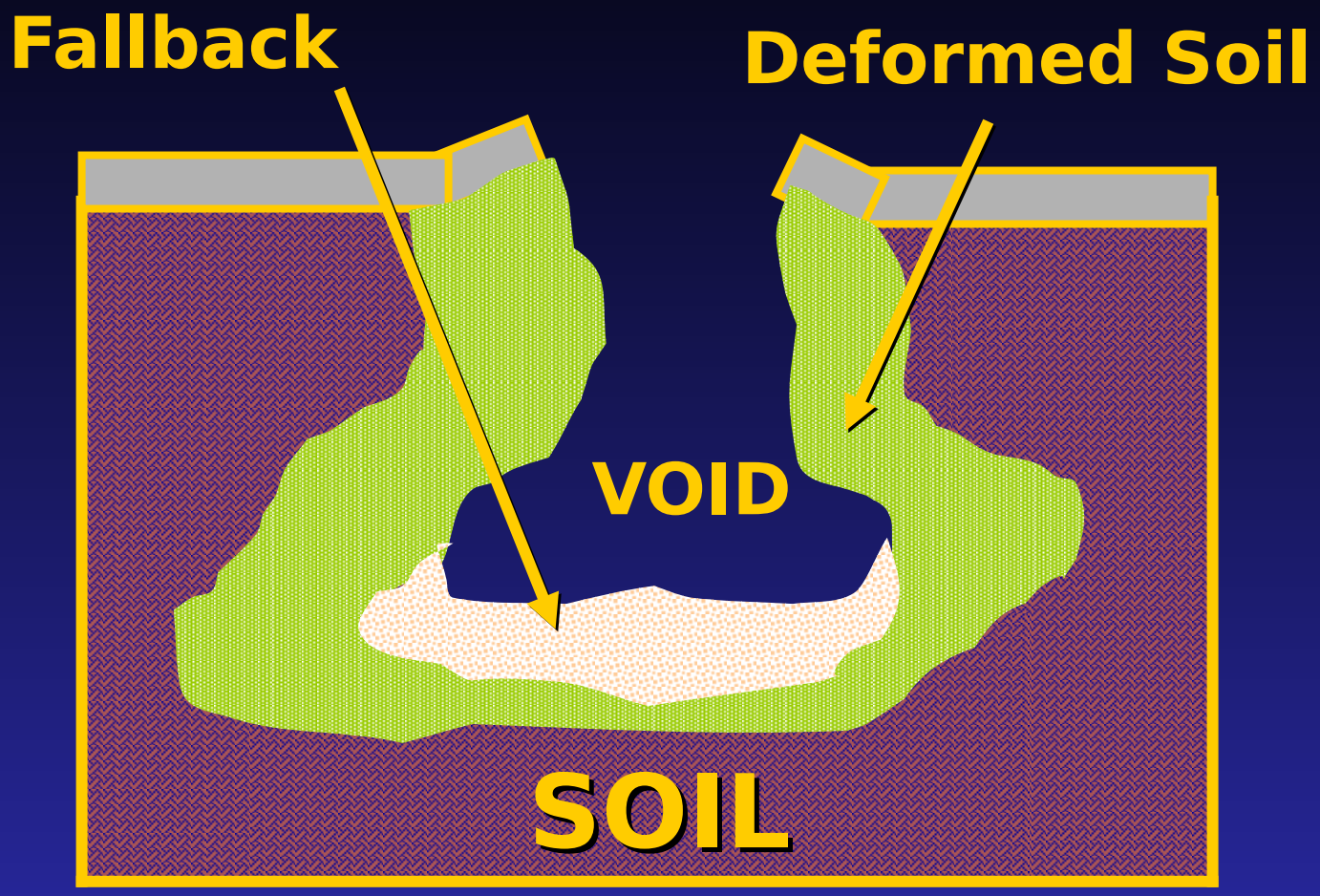
- Large Craters
  - Craters that are 20 feet or greater in apparent diameter
  - Penetrate the base course and sub-grade of the runway
  - Caused by high-angle large caliber naval gunfire, medium to large size bombs (500 pounds or more), and large rockets/missiles
  - Will always have pavement upheaval
  - See Figure 4



Large Crater

Damage Categories

- Camouflet
  - Craters with relatively small apparent diameters
  - Have deep penetration
  - Usually caused by large penetration type projectiles with time delay fuses



Camoflet

Ten Crater Repair Steps

- Remove debris
- Conduct surface roughness test
- Break and remove pavement upheaval
- Remove water
- Backfill
- Level and compact backfill
- Place impervious membrane
- Repair sub-base and base course
- Measure repair sag
- Place FOD cover

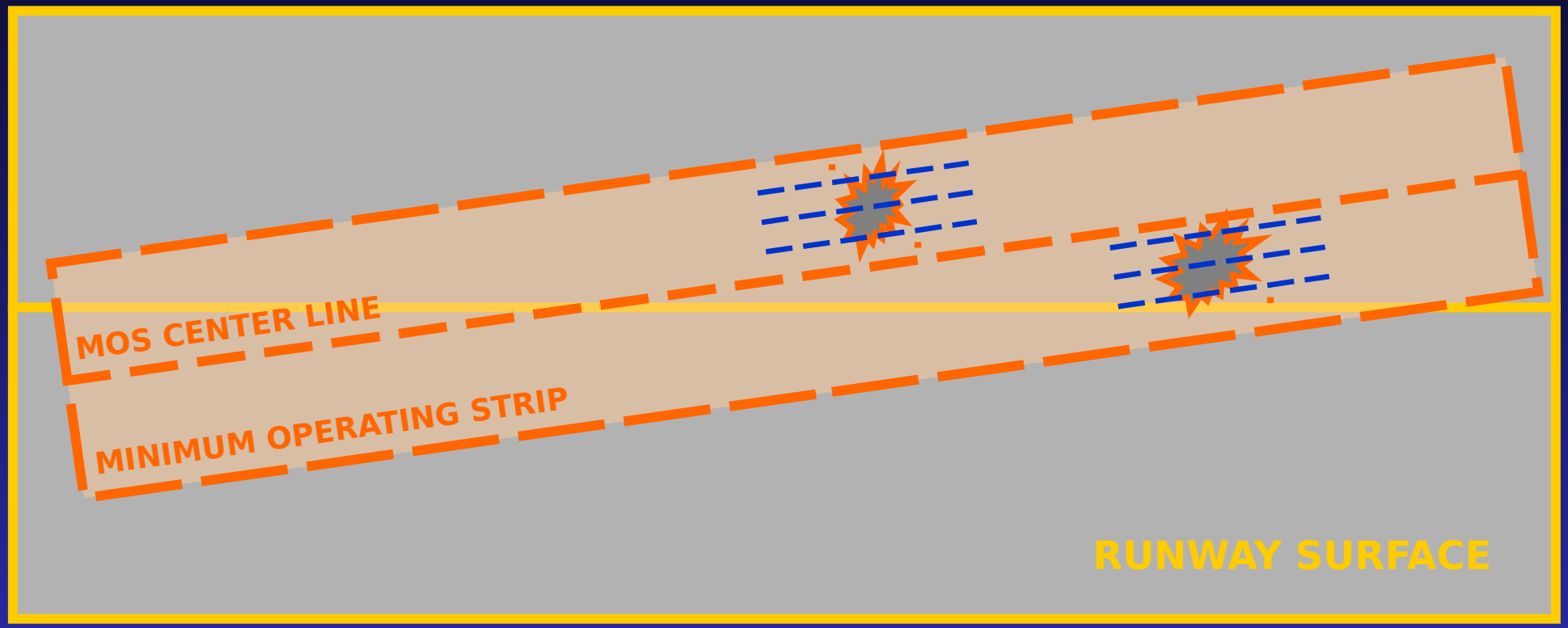
Repair Step 1: Remove Debris

- Clear and remove all debris from around the crater lip
- Ensure up heaved pavement is visible

Repair Step 2: Surface Roughness Test

- Measure upheaval around the crater to determine how much to remove
- Make checks along three lines parallel to the MOS centerline
- In addition, perform the following:
  - Determine repair quality
  - Measure slope
  - Measure height
  - Mark areas to be removed

Surface Roughness Measuring



Repair Step 2: Surface Roughness Test

- Determine Repair Quality
  - Each crater given a repair quality prior to repairs
  - Assigned by the MOS Selection Team in the AGSOC
  - Gives maximum allowable upheaval that can remain above undisturbed pavement

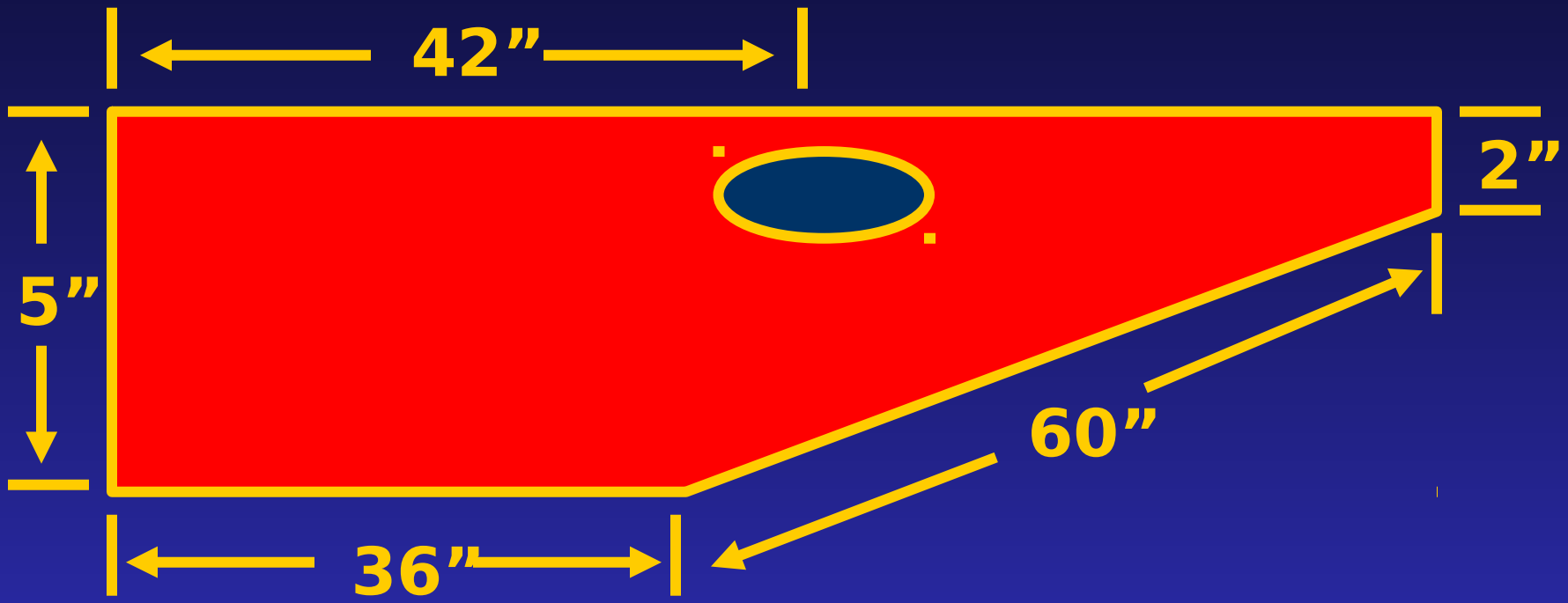
Repair Step 2: Surface Roughness Test

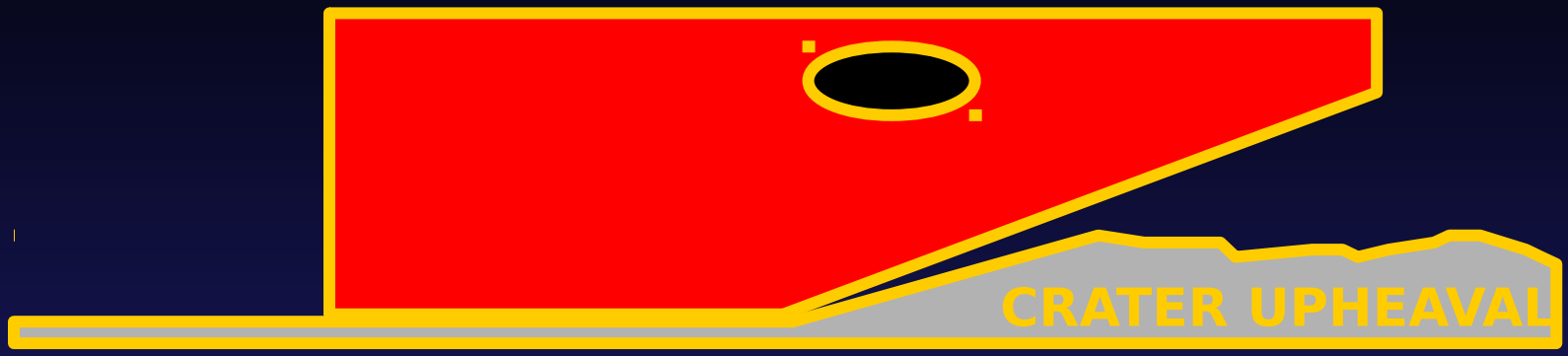
- Crater Repair Qualities
  - "A" Quality - No upheaval above undisturbed surface (Flush repair)
  - "B" Quality - One inch of upheaval above undisturbed surface
  - "C" Quality - One and a half inches of upheaval above undisturbed surface
  - "D" Quality - Three inches of upheaval above undisturbed surface
  - "E" Quality - Four and a half inches of upheaval above undisturbed surface

Repair Step 2: Surface Roughness Test

- Measure Slope
  - Check up heaved pavement around crater with Change of Slope Straight Edge
  - Does Slope meet set criteria of not exceeding five percent
  - If it does not meet criteria, up heaved pavement will need to be removed

Change of Slope Straight Edge





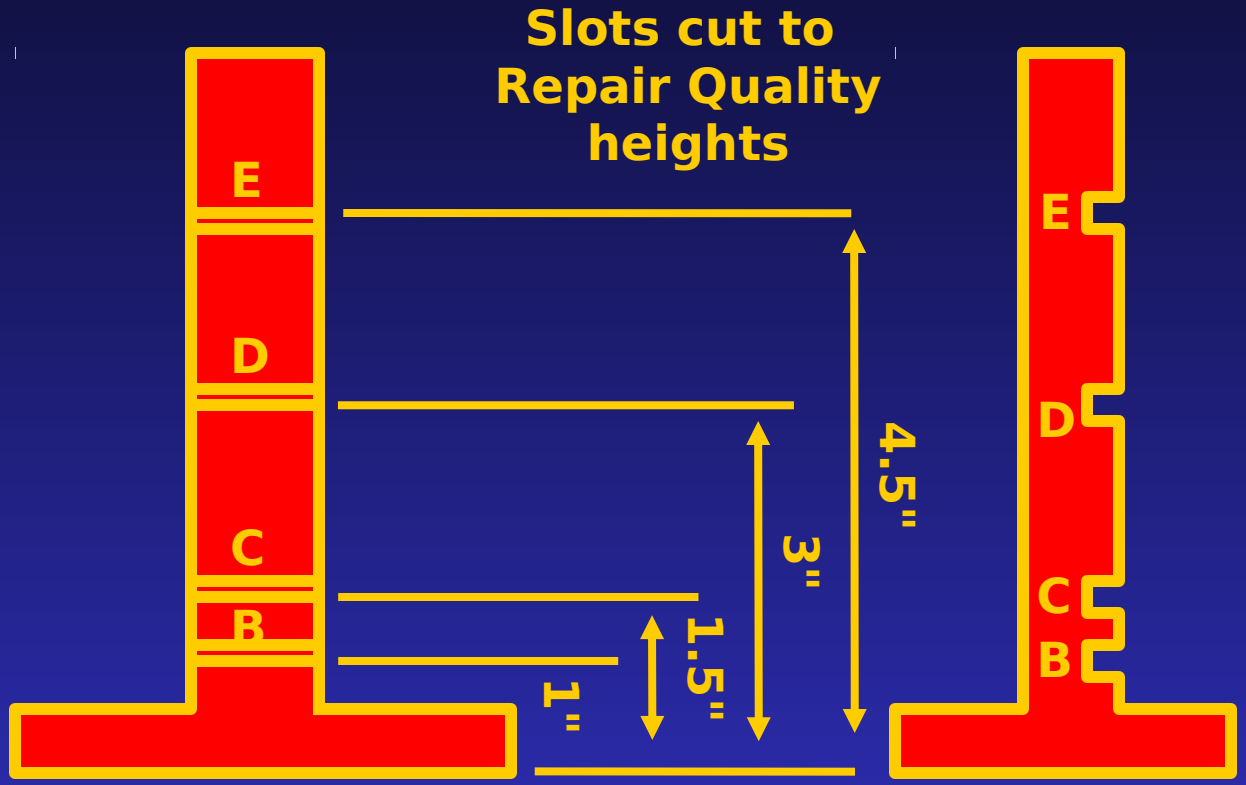
UPHEAVAL SLOPE GOOD TO GO

NEED TO REMOVE UPHEAVAL

Repair Step 2: Surface Roughness Test

- Measure Height
  - Utilize two upheaval height measuring gauges and a string line
  - Measure the height of crater's upheaval above undamaged surface

Surface Roughness Height Measuring Gauge



Repair Step 2: Surface Roughness Test

- Measure Height
  - In order to determine how much upheaval to break out, conduct following:
    - Set string line at repair quality required
    - Move string around crater and mark where upheaval is higher than level of string line (or repair quality)
    - Ensure check made on at least three parallel lines to MOS centerline
    - This upheaval must be removed
    - Make final check following actual repair (Repairs must be within half inch of required quality)


Upheaval Height
Meets Repair Quality
E
D
C
B
A
E
D
C
B
A


Upheaval Height Exceeds
Repair Quality and
Will Have to be Removed
E
D
C
B
A
E
D
C
B
A

Repair Step 2: Surface Roughness Test

- Marking
  - Mark the damaged pavement around each crater to be removed
  - Use paint or other suitable material

Repair Step 3: Remove Upheaved Pavement

- Remove all up heaved pavement identified as not meeting criteria
- Utilize:
  - Blade or ripper on the D7G Dozer
  - Cut with concrete saw
  - Jackhammer
  - Bucket on the Front End Loader
  - Excavator
  - Picks and shovels

Repair Step 4: Remove Water

- Remove any water from the crater prior to back filling and compacting ejecta
- Divert surface water from draining into crater

Repair Step 5: Backfill

- Backfill crater with ejecta and fill material to within 18-24 inches of surface
  - Or Ballast Rock to within 6 inches of surface
- Use no ejecta greater than 12 inches for backfill
- Debris can be used if not wet and the crater is dry
- Ballast Rock is the best choice for a wet crater

Repair Step 6: Level Backfill/compact

- Level backfill with a Dozer blade or by back-blading with a Front End Loader bucket
- Compact
  - Movement of HE in crater often provides enough compaction
  - If vibratory compactor or tamping device of Excavator available, use it
  - Will require hand tamping or small compacting device around the edge of the crater

Repair Step 7: Place Impervious Membrane

- Place impervious membrane (geotextile) over sub-grade backfill
- Cut geotextile to fit crater with edges extending up sides of crater 6-12 inches
- Membrane performs two functions:
  - Prevents water inflow into sub-grade
  - Prevents higher quality stone or select fill from settling into sub-grade

Repair Step 8: Repair Sub and Base Course

- Two methods of crater repairs used:
  - Crushed Stone Method
    - Normal
    - Choked-Ballast
    - Cheap-Ballast
  - Sand Grid Method

Repair Step 9: Measure Sag Of Repair

- Measure Sag
  - Performed after crater repaired
  - Measure the sag of repaired surface below string line of Height Measuring Gauge
  - Distance should not exceed one inch

Repair Step 10: Lay The FOD Cover

- Finishing touch
- Dependent on the type of repair, the repair quality requirement, and the availability of resources
  - Ready mix cement, precast concrete slabs, FRP, and AM-2 matting
  - Crushed stone w/o FOD cover

Methods of Crater Repairs

Crushed Stone Method

- Three types of Crushed Stone Repair:
  - Normal Method
  - Choked-Ballast Method
  - Cheap-Ballast Method
- Typical materials used
  - Crushed Stone:
    - Well graded, high quality stone
    - 1.5” minus aggregate size
  - Ballast Rock = 4” minus aggregate size

Crushed Stone Normal Method

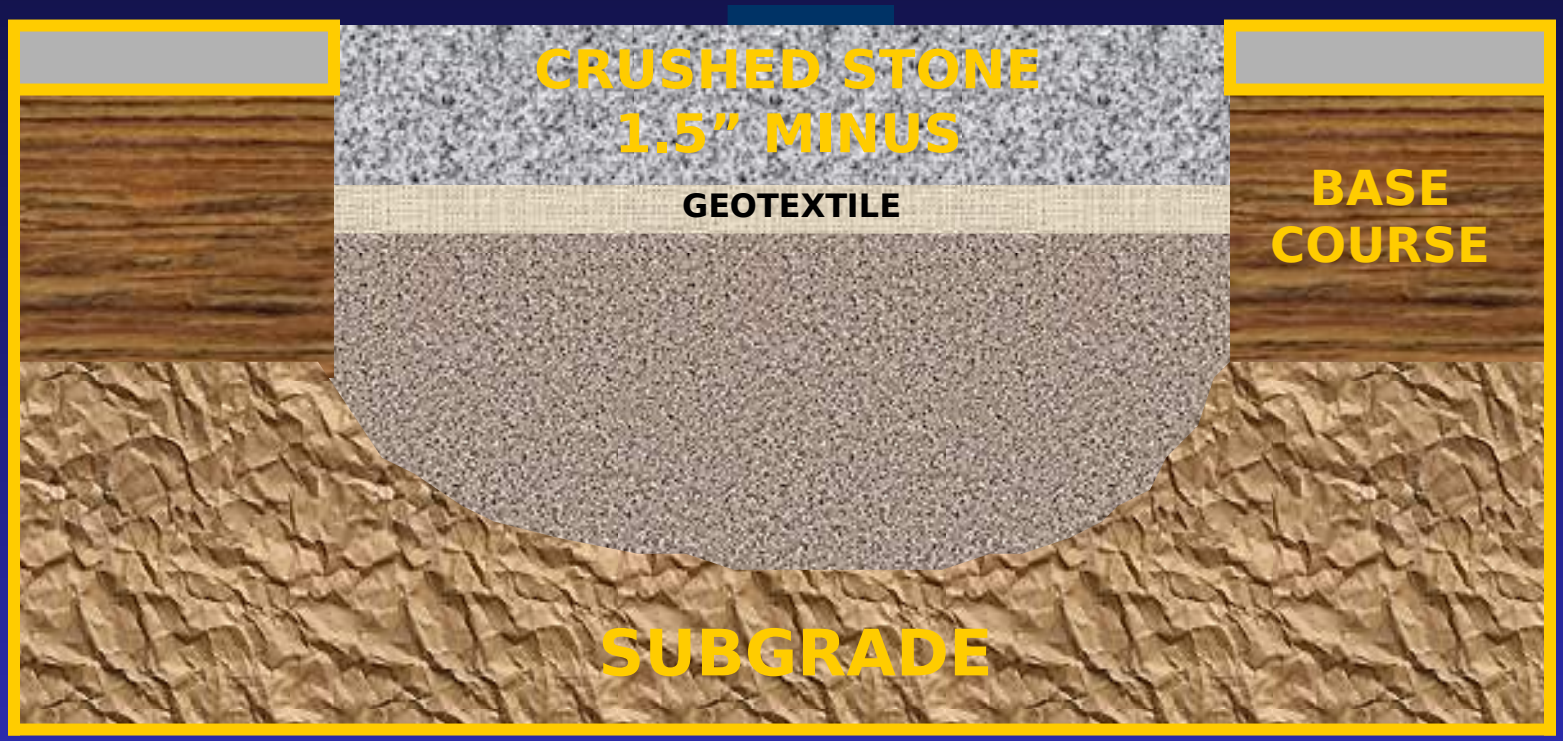
- Used for Dry craters only
- Crater sub-grade backfilled with debris (ejecta) to within 18-24 inches (Steps 1-6)
- Sub-grade covered with impervious membrane (Step 7)
- Crater filled with crushed stone approximately 4 inches above surface
- Crushed stone compacted with roller with excess removed with grader to level repair
- Apply FOD cover

Normal Crushed Stone Crater Repair

Crushed Stone Choked-ballast Method

- Used when crater contains water or debris is unsuitable for backfill
- Crater sub-grade backfilled to within 4-6” of surface with ballast rock (Steps 1-6)
- Sub-grade covered with impervious membrane (Step 7)
- Crater filled with crushed stone approximately 4” above surface
- Crushed stone compacted and scraped level by grader to level of repair criteria
- Apply FOD cover

Choked-Ballast Crushed Stone Repair



Crushed Stone Cheap-ballast Method

- Suitable for dry crater
- Makes max use of cheaper fill material
- Crater sub-grade backfilled to within 14-18 inches of surface with ejecta
- Sub-grade covered with impervious membrane
- Crater backfilled to within 4-6 inches of surface with ballast rock
- Ballast rock covered with membrane

Crushed Stone Cheap-ballast Method

- Crater is filled with crushed stone approximately 4 inches above the surface
- Crushed stone compacted and scraped level by a grader to level of repair criteria
- Apply FOD cover

Cheap-Ballast Crushed Stone Repair

Sand Grid Method

- Made from high density polyethylene plastic
- Expand to 8'x8"x20', forming 561 cells
- Crater preparation and sub-grade construction the same as for crushed stone
- However, it is important to have the sub-grade as close to 20 inches below the surface as possible (tolerance of one inch)

Sand Grid Method Repair Steps

- Place impervious membrane over ejecta backfill
- Stretch, cut and place first layer of sand grids in crater
- Ensure sand grids fill entire crater as close as possible
- Fill the sand grids using a Front End Loader
- Level the sand, leaving two inches above the surface of the sand grid
- Place second layer of sand grids in the crater

Sand Grid Method Repair Steps

- Fill the sand grids using a Front End Loader
- Overfill second layer by 6 inches
- Compact sand with roller
- Grade off excess sand
- Clean and sweep area
- Apply FOD cover

Sand Grid Method
Crater Repair

Methods of FOD Cover

FOD Cover

- Next step is to add some type of operating surface or FOD cover
- Five FOD Covers used within DOD
  - Rapid Set Concrete
  - Pre-cast Concrete Panels
  - AM-2 Matting
  - FRP
  - Asphalt

FOD Cover

CRATER REPAIR	RAPID SET CONCRETE	PRECAST CONCRETE	AM-2 MATTING	FRP	ASPHALT
CRUSHED STONE	X	X	X	X	X
SAND			X	X	

Marine Corps FOD Cover

- Rapid Set Concrete
- Pre-Cast Concrete Panels
- Fiberglass Reinforced Polyester Panels
- AM-2 Matting

Rapid Set Concrete FOD Cover

Rapid Set Concrete FOD Cover

- Quick drying cement mixed with water, sand, and aggregate
- Hardens within 30 minutes after mixing
- Can be batched by either a concrete mixer or by hand
- This repair is considered permanent in nature and other improvements are not necessary

Precast Concrete Slabs FOD Cover

Precast Concrete Slabs FOD Cover

- Panels are 2m x 2m concrete slabs
- Used extensively by NATO in northern climates where cold weather does not allow the use of Rapid Set Concrete

FRP Panels
FOD Cover

FRP Panels
FOD Cover

- Made of two or more layers of fiberglass impregnated with either polyurethane or polyester resin
- Panels are 1/4” - 3/8” in thickness
- Preferred method of FOD cover for a quick and temporary repair
- Limited quantities in inventory

AM-2 Matting FOD Cover

AM-2 Matting FOD Cover

- Can be used for FOD cover on taxiways without extensive preparation
- Not desired for runways due to surface roughness requirements
- Runway could be cut to allow flush fit, but very time consuming

Crushed Stone w/o FOD Cover

Crushed Stone w/o FOD Cover

- This method will only be used until sufficient quantities of FRP Panels or concrete slabs are obtained or other permanent repairs can be made

- Can be used during evacuation of an air base

Methods of Spall Repair

Spall Repair Methods

- Estimated 400 Spalls on the airfield
- Five generally accepted methods:
  - Silikal
  - Cold Mix Asphalt
  - Magnesium Phosphate
  - Portland Cement
  - Penatron

Spall Repair Methods SILIKAL

- Is a polymer concrete
- Commercial Silikal not accepted
- Made by mixing Silikal powder with liquid hardener and catalyst
- Can be extended with addition of pea gravel
- When used below freezing, an accelerator must be used

Spall Repair Methods SILIKAL

- Advantages
  - Hardens rapidly
  - Can support Aircraft traffic after 30-60 minutes
  - Extended shelf life (5 years)
- Disadvantages
  - Store at moderate temperatures
  - Must be kept dry
  - Silikal's catalyst is highly flammable
  - Silikal's accelerator is highly toxic
  - Can damage asphalt pavement

Spall Repair Methods
Cold Mix Asphalt

- Amalgapave and Future Patch are two cold mix asphalt that are recommended
- Amalgapave and Future Patch can be used for larger spalls up to 5 feet in diameter
- Conventional cold mix asphalt suitable for small spalls up to 2 feet in diameter and 6 inches deep

Spall Repair Methods
Cold Mix Asphalt

- Advantages
  - Stored in ready to use condition
- Disadvantages
  - Stability and toughness less than hot mix asphalt
  - Can be stockpiled in dry storage for approximately 1 year
- Planning Purposes
  - 10 tons of cold mix asphalt will repair approximately 100 average size spalls (less than 2 feet in diameter and 6 inches deep)

Spall Repair Methods Magnesium Phosphate

- Cement similar to Portland cement
- Commercially available
- Can be extended 50 percent by the addition of small gravel
- Mixed in small concrete mixer for about 1 to 2 minutes
- Only mix quantity that will be used immediately
- Sets rapidly, depending on temperature

Spall Repair Methods Magnesium Phosphate

- Advantages
  - Can be used in wet spalls
  - Faster setting than Portland cement
- Disadvantages
  - Must be kept in dry storage
  - Has a shelf life of approximately 1 year
- Planning Purposes
  - 7 tons of magnesium phosphate, extended by 50 percent of small gravel, will provide approximately 10 cubic yards of repair material

Spall Repair Methods Portland Cement

- Most commonly used of modern hydraulic cements
- Advantages
  - Fireproof, watertight, comparatively economical, and easy to use
- Disadvantages
  - Must be kept in dry storage
  - Prone to thermal movements, shrinkage, and creep

Spall Repair Methods PENATRON

- Polymer made by mixing two components
- Can be extended by adding pea gravel into the spall
- Forms a bond with the rock and concrete
- Advantages
  - Material begins to set in 7-9 minutes
  - Has a drive over time of 45 minutes
  - Has a relatively long shelf life

Spall Repair Methods PENATRON

- Disadvantages
  - Is very expensive
  - Can damage asphalt pavement

Summary

- Different types of AF Damage expected
- Crater Repair Steps for Sub-grade and Base Course
- Various Crater Repair Methods available
- Crater Repair with FOD Cover
- Methods of Spall Repair